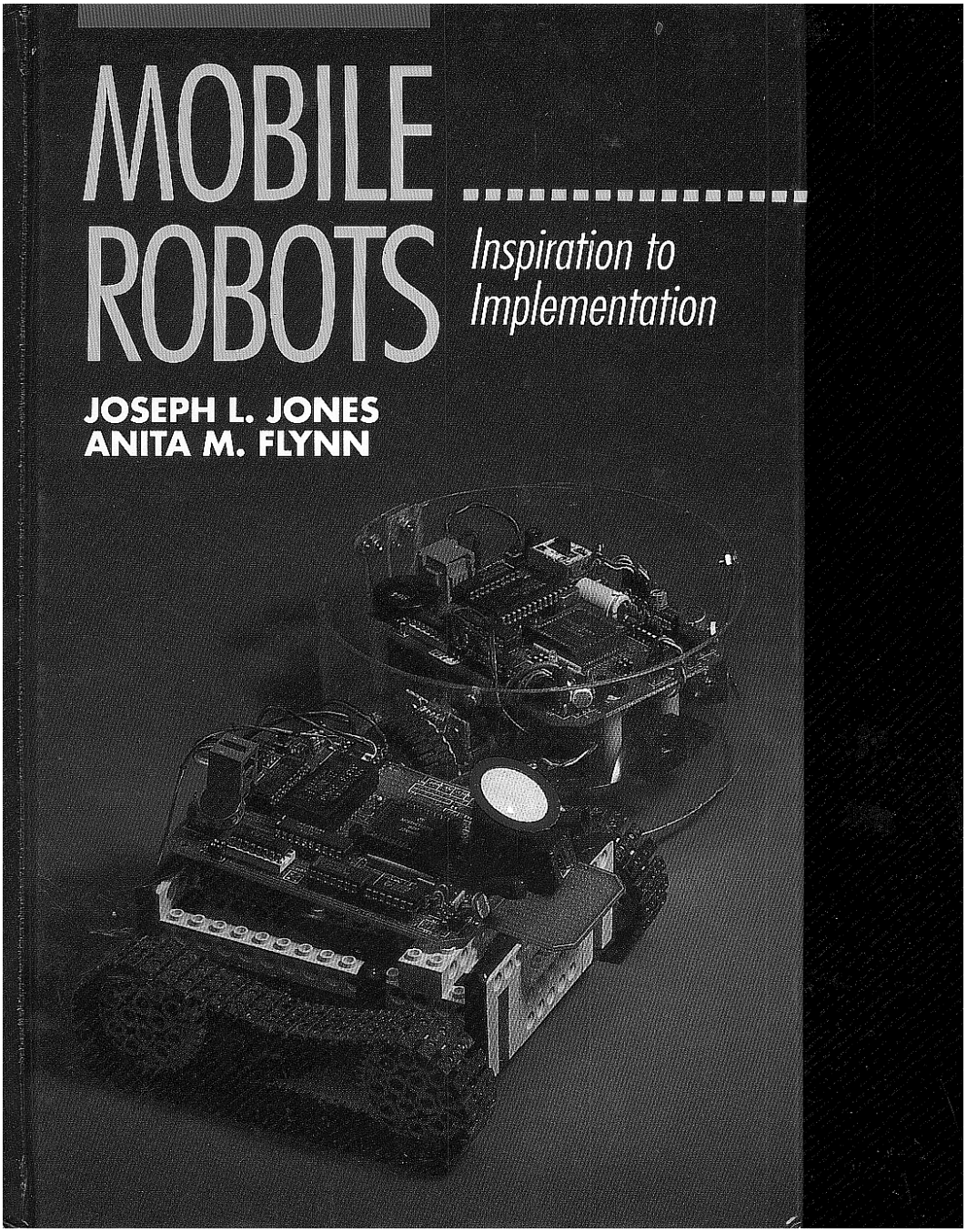
Jameco Part number 154131



Jameco Part number 154131

Contents

Preface xiii

Acknowledgments Xviii

1 Introduction **1**
1.1 References 9

2 TuteBot **11**
2.1 A Tutorial Robot 11
2.1.1 TuteBot Behaviors 13
2.2 Building TuteBot 16
2.2.1 Electronic Components 21
2.2.2 Electronic Construction 25
2.2.3 Operation 29
2.2.4 Exercise 35
2.3 References 36

3 Computational Hardware **37**
3.1 Rug Warrior's Design Strategy 38
3.1.1 Interactive C 39
3.2 Microprocessors 41
3.3 The Canonical Computer 42
3.3.1 The Processor 43
3.3.2 The Bus 45
3.3.3 Memory 45
3.3.4 Ports 47
3.4 Rug Warrior Logic 49
3.4.1 Power 49
3.4.2 The Clock 49
3.4.3 Reset 50
3.4.4 Mode Selection 50
3.4.5 Low-voltage Inhibit 50

Contents

3.4.6 The Serial Line 50
3.4.7 External Memory 51
3.4.8 Battery Backup 52
3.5 Hardware-Software Interface 52
3.5.1 Representing Numbers 52
3.5.2 An Example 53
3.5.3 CPU Registers 56
3.5.4 Instructions and Operands 57
3.5.5 Arithmetic 60
3.5.6 Control and Status Registers 60
3.5.7 Jumps and Branches 61
3.5.8 Subroutines 62
3.5.9 The Stack 64
3.5.10 Passing Arguments 64
3.6 Real-Time Control 66
3.6.1 Polling 66
3.6.2 Interrupts 68
3.6.3 Input Capture 70
3.6.4 Traps 72
3.6.5 I/O Buffers 72
3.7 Loading a Program 73
3.7.1 The Assembly Program 73
3.7.2 A Bootstrap Loader 75
3.8 Alternatives 76
3.9 References 77

4 Designing and Prototyping 79
4.1 Practical Problems 79
4.1.1 Attention to Detail 80
4.1.2 Wire-Wrap 80
4.1.3 Scotchflex 81
4.1.4 Speedwire 83
4.2 Connectors 85
4.3 Printed Circuit Boards 89
4.4 Debugging 91

5 Sensors 93
5.1 Achieving Perception 93
5.1.1 Transducing versus Understanding 93
5.1.2 Levels of Abstraction 94
5.2 Interfacing Sensors 94
5.2.1 Software Drivers 96

Contents

5.2.2 Sensitivity and Range 99
5.3 Light Sensors 101
5.3.1 Photoresistors 102
5.3.2 Near-Infrared Proximity Detectors 106
5.3.3 Pyroelectric Sensors 111
5.3.4 Cameras 114
5.4 Force Sensors 114
5.4.1 Microswitches 114
5.4.2 Bend Sensors 117
5.4.3 Force-Sensing Resistors 117
5.5 Sound Sensors 117
5.5.1 Microphones 117
5.5.2 Piezoelectric Film Sensors 119
5.5.3 Sonar 119
5.6 Position and Orientation 121
5.6.1 Shaft Encoders 122
5.6.2 Gyros 131
5.6.3 Tilt Sensors 132
5.6.4 Compasses 133
5.7 Proprioceptive Sensors 134
5.7.1 Battery-Level Sensing 134
5.7.2 Stall Current Sensing 135
5.7.3 Temperature 136
5.8 Exercise 136
5.9 References 137

6. Mechanics **139**
6.1 Locomotion 139
6.1.1 Wheel Arrangements 141
6.1.2 Robot Kinematics 145
6.1.3 Robot Shape 147
6.2 Adapting Mobile Platforms 148
6.2.1 Identifying the Drive Type 148
6.2.2 Electrical Modifications 150
6.3 Legged Locomotion 151
6.4 Construction Systems 152
6.5 Custom Construction 153
6.5.1 Wheel Mounting 153
6.5.2 Sheet Metal 155
6.5.3 Acrylic 157
6.6 Exercise 159
6.7 References 159

Jameco Part number 154131

Contents

7 Motors **161**
7.1 Variety Abounds 161
7.2 How a DC Motor Works 166
7.3 Sizing a DC Motor 170
7.3.1 Torque, Speed, Power, and Energy 170
7.3.2 A Motor Model 171
7.3.3 Speed-Torque Curves 174
7.4 Gears 177
7.5 Motor Data Sheets 179
7.6 Motors for Rug Warrior 183
7.6.1 A Vehicle Model 183
7.6.2 Selecting a Motor 185
7.6.3 Converting Servo Motors 185
7.6.4 Unmodified Servo Motors 189
7.7 Interfacing Motors 191
7.7.1 H-Bridges 191
7.7.2 Switching Inductive Loads 193
7.7.3 Power Electronics 195
7.7.4 Motor-Driver-Power ICs 208
7.8 Software for Driving Motors 210
7.8.1 Pulse-Width Modulation 212
7.8.2 Feedback-Control Loops 218
7.9 References 224

8 Power **227**
8.1 Batteries 227
8.1.1 Chemistry 228
8.1.2 Energy Density 231
8.1.3 Voltage 231
8.1.4 Capacity 232
8.1.5 Internal Resistance 233
8.2 Recharging 233
8.3 Power Regulation 234
8.3.1 Avoiding Regulation 234
8.3.2 Linear Regulators 235
8.3.3 DC-DC Converters 236
8.4 Isolation 238
8.5 References 241

Jameco Part number 154131

Contents

9 Robot Programming **243**
9.1 The Traditional Approach 243
9.1.1 Computation 246
9.1.2 Modeling 246
9.1.3 Time 247
9.2 The Subsumption Approach 247
9.2.1 Behavior Networks 248
9.3 Rug Warrior's Program 251
9.4 Implementing Subsumption 253
9.4.1 Processes and Schedulers 253
9.4.2 Finite-State Machines 254
9.4.3 A Subsumption Formalism 255
9.5 Subsumption in **IC** 259
9.6 What Did We Do? 266
9.7 References 268

10 Unsolved Problems **271**
10.1 Navigation 272
10.2 Recognition 272
10.3 Learning 272
10.4 Gnat Robots 273
10.5 Cooperation 273
10.6 Thoughts 274
10.7 Exercise 274
10.8 References 275

A Schematics **277**

B Rug Warrior Program **287**

C Yellow Pages **299**
C.1 Suppliers 300
C.2 Products 318

D Trade Magazines **321**

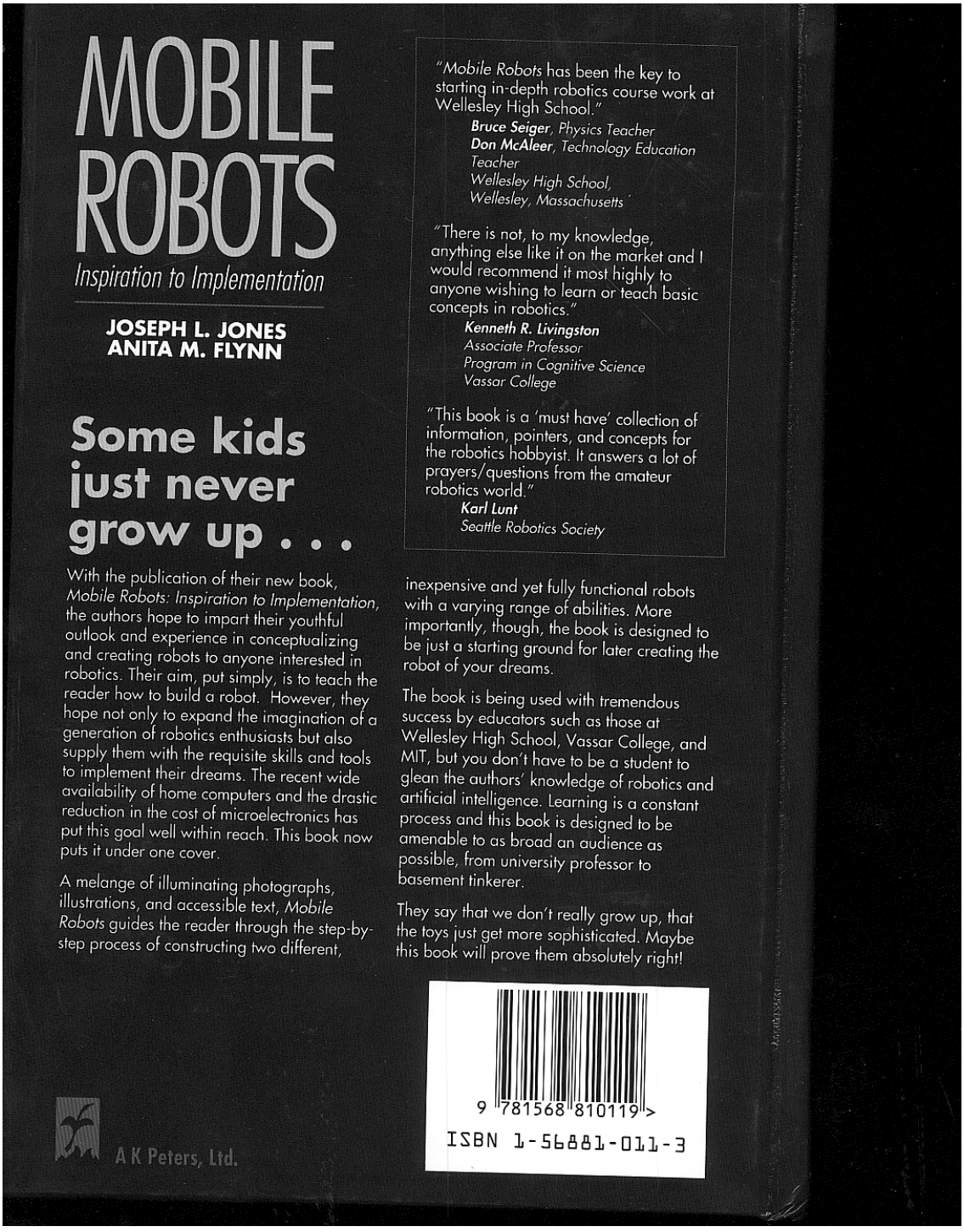
E Data Books **325**

F Color and ASCII Codes **335**

Bibliography **337**

Index **343**

Jameco Part number 154131



MOBILE ROBOTS

Inspiration to Implementation

JOSEPH L. JONES
ANITA M. FLYNN

"*Mobile Robots* has been the key to starting in-depth robotics course work at Wellesley High School."

***Bruce Seiger**, Physics Teacher*
***Don McAleer**, Technology Education Teacher*
Wellesley High School,
Wellesley, Massachusetts

"There is not, to my knowledge, anything else like it on the market and I would recommend it most highly to anyone wishing to learn or teach basic concepts in robotics."

Kenneth R. Livingston
Associate Professor
Program in Cognitive Science
Vassar College

"This book is a 'must have' collection of information, pointers, and concepts for the robotics hobbyist. It answers a lot of prayers/questions from the amateur robotics world."

Karl Lunt
Seattle Robotics Society

Some kids just never grow up . . .

With the publication of their new book, *Mobile Robots: Inspiration to Implementation*, the authors hope to impart their youthful outlook and experience in conceptualizing and creating robots to anyone interested in robotics. Their aim, put simply, is to teach the reader how to build a robot. However, they hope not only to expand the imagination of a generation of robotics enthusiasts but also supply them with the requisite skills and tools to implement their dreams. The recent wide availability of home computers and the drastic reduction in the cost of microelectronics has put this goal well within reach. This book now puts it under one cover.

A melange of illuminating photographs, illustrations, and accessible text, *Mobile Robots* guides the reader through the step-by-step process of constructing two different, inexpensive and yet fully functional robots with a varying range of abilities. More importantly, though, the book is designed to be just a starting ground for later creating the robot of your dreams.

The book is being used with tremendous success by educators such as those at Wellesley High School, Vassar College, and MIT, but you don't have to be a student to glean the authors' knowledge of robotics and artificial intelligence. Learning is a constant process and this book is designed to be amenable to as broad an audience as possible, from university professor to basement tinkerer.

They say that we don't really grow up, that the toys just get more sophisticated. Maybe this book will prove them absolutely right!

9 781568 810119 >
ISBN 1-56881-011-3

A K Peters, Ltd.